Comments on a Paper by G. Marconi/by John Evans

The paper presented by Guglielmo Marconi on December 11, 1909, on the occasion of his being awarded the Nobel Prize for his work on wireless telegraphy, is remarkable for both the insights it portrays as well as the misunderstandings. Most significant among the latter was the fact that, while Marconi correctly reasoned that there existed a layer in the upper atmosphere in which ultraviolet from the sun created charged particles, which accounted for the day-to-night variation of signal intensity (absorbing the signals by day), he failed to recognize the role of the ionosphere in making long-distance conmmunication possible (over the curved surface of the earth). Rather, he believed all his long-distance communication results were achieved using ground waves.

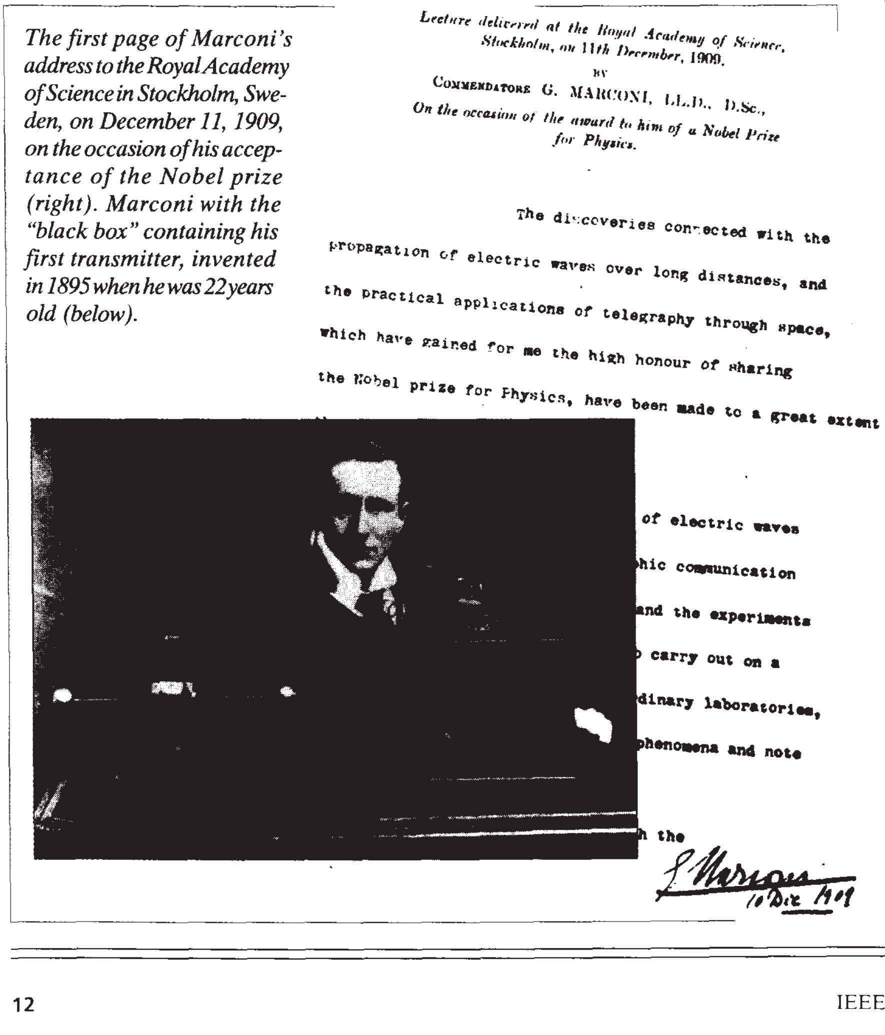
It is useful, however, to recap Marconi's very real achievements in establishing the utility of wireless telegraphy. While others (e.g., Sir Oliver Lodge) had demonstrated the transmission and reception of Hertzian waves bearing useful intelligence over short distances, it was Marconi who systematically set about to achieve a practical system of wireless telegraphy capable of functioning over considerable distances and providing a commercial service. Marconi's first significant contribution to the art (such as it was at the time) was to abandon the use of Hertzian dipole antennas (capable of transmitting only the very short waves generated by spark transmitters) in favor of a vertical wire aerial (usually capacitively loaded) together with a ground return. This radiated a vertically polarized wave, which is less attenuated over lossy ground than a horizontal wave. Moreover, such an aerial could radiate much longer waves, thereby further reducing the ground-wave attenuation encountered. Finally, the radiation from such an antenna tends to be at a low elevation angle rather than straight up (as is the case for a dipole placed only a fraction of a wavelength above ground).

Next, he understood the use of tuning for resonance (called "syntony" at the time) as a means of concentrating the energy of his spark transmitters into a narrow wavelength range and for improving the sensitivity of his receivers. Moreover, he employed transformer matching to couple the (low) impedance of his aerial circuit to the (high) impedance of his oscillator circuit. Finally, he began to use tuned, i.e., resonant, aerial systems (with inductive base-loading and/or capacitive top-loading) to improve the antenna efficiency. Then, using larger and larger antenna systems, he was able to operate at longer and longer wavelengths and achieve reasonably reliable transatlantic communications both by day and by night. He correctly recognized that horizontal wires do not radiate equally in all directions, and hence their addition to his aerials could give them some directivity.

Marconi also made (or oversaw) many improvements to the wireless apparatus used. More powerful spark transmitters were developed, finally leading to ones in which a chopper wheel is placed in the arc circuit to generate a continuous stream of pulses of (damped) oscillations. These gave a musical tone to the signals and helped receiving operators distinguish between several stations. Improvements were also made to the receiver, first with a more reliable coherer receiver and later with a "magnetic receiver" that depended on the change of magnetic hysteresis that occurs in iron when exposed to high frequency currents.

While one may be accused of having the benefit of hindsight, it still seems remarkable that Marconi gave no mention in his paper of the suggestion made, shortly after his successful transatlantic experiments (independently) by Kennely and Heavyside, that the waves were being reflected back to earth by an electrically conducting region high in the earth's atmosphere. Yet he was well aware that theoreticians had concluded that the ground wave could not long follow the curved surface of the earth. Moreover, the suggestion by Kennely and Heavyside was not altogether new. Balfour Stewart had made the same suggestion in 1888 to account for short-lived fluctuations in the earth's magnetic field.

Evidently, Flemming's work on why the ground wave propagated better over sea water than ground (which was in accord with Marconi's observations)



The first page of Marconi's address to the Royal Academy of Science in Stockholm, Sweden, on December 11, 1909, on the occasion of his acceptance of the Nobel prize (right). Marconi with the "black box" containing his first transmitter, invented in 1895 when he was 22 years old (below).

Lecture delivered at the Royal Academy of Science, Stockholm, on 11th December, 1909.
BY
COMMENDATORE G. MARCONI, LL.D., D.Sc.,
On the occasion of the award to him of a Nobel Prize for Physics.

The discoveries connected with the propagation of electric waves over long distances, and the practical applications of telegraphy through space, which have gained for me the high honour of sharing the Nobel prize for Physics, have been made to a great extent

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G Marconi
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seems to have convinced him that this was the mode of propagation at all distances. In this connection Marconi stated, "With regard to the presumed obstacle of the curvature of the earth, I am of opinion that those who anticipated difficulties in consequence of the shape of our planet had not taken sufficient account of the particular effect of the earth connection to both transmitter and receiver, which earth connection introduced effects of conduction which were generally at that time overlooked. Physicists seemed to consider for a long time that Wireless Telegraphy was solely dependent on the effects of free Hertzian radiation through space, and it was years before the probable effect of the conductivity of the earth between the stations was satisfactorily considered or discussed. Professor J. A. Fleming in his book on "The Principles of Electric Wave Telegraphy" gives diagrams showing what is now believed to be the diagrammatic representation of the detachment of semi-loops of electric strain from a simple vertical wire. As will be seen these waves do not propagate in the same manner as free radiation from a classical Hertzian oscillator, but glide along the surface of the earth."

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Yet the clues to the correct interpretation were all there. There is a day-to-night variation in intensity (caused by the D region), about which he stated: "I am now inclined to believe that the absorption of electric waves during daytime is due to the ionization of the gaseous molecules of the air affected by ultra-violet light, and as the ultra-violet rays, which emanate from the sun, are largely absorbed in the upper atmosphere of the earth, it is probable that the portion of the earth's atmosphere which is facing the sun will contain more ions or electrons than that portion which is in darkness, and therefore, as Sir J. J. Thomson has shown, this illuminated and ionized air will absorb some of the energy of the electric waves." If the sun created ionization in the upper atmosphere, might there not be regions above the *absorbing* level that were capable of *reflecting* radio-waves?

He had, moreover, observed the "skip" phenomenon when nearby shore stations could not detect signals, but more distant ones could. He noted: "Thus an ordinary ship station, utilizing about 1/2 a Kilowatt of electrical energy, the normal range of which is not greater than 200 Miles, will occasionally transmit messages across a distance of over 1200 Miles. It often occurs that a ship fails to communicate with a nearby station, but can correspond with perfect ease with a distant one." Might this not be caused by a gap between the farthest distance the ground wave could be heard and the shortest distance at which the skywave arrived? Finally, he had observed a wavelength dependence of the propagation (at LF) at sunrise and sunset. Might this not be caused by a change in the height of the earth-ionosphere waveguide altering the mode structure between two stations?

Perhaps the real reason Marconi did not accept the idea of a reflecting layer was the fact that no one at that time had any idea of the true extent of the earth's atmosphere, and hence the height of the reflecting region. Marconi apparently believed it to be of very limited extent since he postulated that the cloudy conditions prevailing in England hindered the penetration of the ultra violet responsible for the absorbing layer (now known to be between 75 and 100 Km) and hence made for good propagation conditions in that country. "The fact remains, however, that for comparatively short waves such as are used for ship communication clear sunlight and blue skies, though transparent to light, acts as a kind of fog to these waves. Hence the weather condition prevailing in England, and perhaps in this Country, are usually suitable for Wireless Telegraphy." Another 15 years were to pass before another Nobel prize winner, Sir Edward Appleton, first measured the height of reflection for medium wave (broadcast band) signals (approximately 120 Km) and put the matter to rest.

Perhaps most striking about Marconi's work is how well it demonstrates the need in science for experimenters, who proceed with their experiments despite all of the "theoretical" arguments available at the time that they can't possibly work. In the rare cases when they do work, valuable new knowledge is invariably gained.

Biography

JOHN V. EVANS is president of COMSAT Laboratories. He joined COMSAT in April 1983. (COMSAT Laboratories has a staff of 220, an annual budget of $32 million, and is the largest research center devoted entirely to satellite communications research.) Before coming to COMSAT, Dr. Evans was with the M.I.T. Lincoln Laboratory, which he joined in 1960. He is a graduate of Manchester University, England, with degrees in physics.

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